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The effect of grain size reduction for the origin of the mid-lithosphere discontinuity

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In the last decades, the high heterogeneity of lithospheric mantle in term of its physical properties and chemical compositions is widely documented by geophysical, petrological, and geochemical studies. A sharp discontinuity in seismic velocity (~2-10% reduction over no more than 30-40 km) is detected at 60 – 160 km depth in the continental lithosphere and at an average depth of 70 km in the oceanic lithosphere. Several models have been proposed for the genesis of this mid-lithosphere discontinuity (MLD) that include (1) presence of partial melts or fluids, (2) layered anisotropy, (3) layered composition, and (4) elastically accommodated grain boundary sliding. However, all of these models have some limitations and cannot explain all the characteristics of the MLD. Here we propose a new model for the genesis of the MLD and explore its mechanism through thermomechanical numerical modeling at subduction zones. In the model, the deforming lithospheric mantle is affected by grain size reduction and growth processes. Numerical results show that the lithospheric deformation induced by subduction causes the grain size to sharply decrease within the 10-20 km thick brittle/ductile transition zone over significant regions inside the lithosphere. The depth depends mainly on the age of oceanic lithosphere and the thickness of continental lithosphere and is consistent with the observations. In addition, based on the previous study of dislocation slip-system and related olivine fabrics in the mantle, grain size reduction plays an important role in fluid pumping and phase nucleation through grain boundaries. This may in turn produce an increased intra-lithospheric water content resulting in high electrical conductivities and large seismic velocity drops at the MLD depths.